

are decomposed by the removal of two carbon atoms at a time, a process he named *β -oxidation* (Knoop, 1904).³⁵

In the first four decades of the twentieth century biochemists made great strides in developing sketches of the mechanisms underlying many metabolic processes. In particular, by 1940 they had developed detailed accounts of the biochemical mechanisms involved in fermentation (glycolysis) and aerobic cellular respiration. The research on fermentation was a singular success story for biochemistry, largely because the reactions occur freely in the cytoplasm and do not depend on cellular organization. With respect to aerobic respiration, biochemists were successful in identifying the major pathways, but their inability to carry out the full process in preparations that did not include membranes suggested a linkage with cell structure that they lacked the tools to investigate. They also faced problems in explaining the generation of ATP from the component operations of respiration and it turned out this step depended critically on the linkage to cell structure.

Alcoholic and Lactic Acid Fermentation (1895–1940)

As noted previously, the orthodox view that fermentation required living yeast was finally undercut by Eduard Buchner in 1897. Buchner had added sugar to what he termed *press juice* (later called *yeast juice* or *cell-free extract*), made by adding water to ground yeast, and then filtering it under pressure. He made his discovery while collaborating with his brother, Hans Buchner, in grinding bacterial cells with the goal of isolating proteins that might be serving as the active bacterial agents. The endeavor was initially obstructed by the inability to remove remnants of cell bodies from the preparation, but in 1896 Hans Buchner's collaborator, Martin Hahn, developed a technique for filtering the cell structure debris from ground yeast. The Buchners added sugar to the resulting juice, thinking it would serve as a preservative, but the resulting formation of carbon dioxide made Eduard Buchner realize that they had achieved something of far more importance: cell-free fermentation.

Initially Buchner took fermentation to be a single chemical reaction, and coined the name *zymase* for the responsible enzyme. In further research, though, Buchner found evidence that "lactic acid plays an important role in

³⁵ Holmes noted that Knoop in this publication set for himself the "ultimate goal of a complete knowledge of the cleavage and oxidative processes of the building materials and foodstuffs of the animal body" (Knoop, 1904, p. 3, translated by Holmes, 1992, p. 59).